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| | |
|---|---|
| 1. REPORT NO. EPA-600/2-76-179 | 2. |
| 3. RECIPIENT'S ACCESSION NO. | |
| 4. TITLE AND SUBTITLE: The Cost of Municipal Water Supply: A Case Study | 5. REPORT DATE: July 1976 (Issuing Date) |
| | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S): Robert M. Clark, Richard Stevie and Greg Trygg | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS: Municipal Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268 | 10. PROGRAM ELEMENT NO. PE 1CC614 |
| | 11. CONTRACT/GRANT NO. |
| 12. SPONSORING AGENCY NAME AND ADDRESS: Same as above | 13. TYPE OF REPORT AND PERIOD COVERED |
| | 14. SPONSORING AGENCY CODE EPA-ORD |
| 15. SUPPLEMENTARY NOTES | |

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This report utilizes the Cincinnati Water Works of Cincinnati, Ohio, for a case study to examine these factors and to document the application of a functional approach to the analysis of water supply costs. Such an approach can provide the basis for determining the cost of service for any given consumer within the Water Works service area. Ultimately the functional costing approach outlined in this report, or one similar in nature, will of necessity be used to analyze the impact of regional water supply systems.

Data for 10 years are analyzed for each of the functional categories of: Support Services, Acquisition; Purification; Power and Pumping; and Transmission. Operating and Maintenance costs, Capital costs, and Labor costs are evaluated. A system evaluation is performed, in which the above costs are aggregated in such a way as to develop "cost zones" for the Water Works service area. Cost comparisons are made between actual charges and constructed costs for the Water Works' 10 largest water users.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Urban planning; cost analysis; economic analysis; economics; management; planning; regional planning; research; systems engineering; utilities; water supply | PRICES SUBJECT TO CHANGE | 13-B |

| | | |
|---|---|---|
| 18. DISTRIBUTION STATEMENT: Release to public | 19. SECURITY CLASS *(This Report)*: Unclassified | 21. NO. OF PAGES: 95 |
| | 20. SECURITY CLASS *(This page)*: Unclassified | 22. PRICE: 4.00 |

EPA Form 2220-1 (9-73)

☆ U.S. GOVERNMENT PRINTING OFFICE 1976-657-659/5459 Region No. 5-11

EPA-600/2-76-179
July 1976

# THE COST OF MUNICIPAL WATER SUPPLY:

# A CASE STUDY

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CINCINNATI, OHIO 45268

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## FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, four water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

The Safe Drinking Water Act of 1974 has focused a growing awareness on problems related to water supply and water supply utility management. A major portion of the Act concerns itself with the economics of water supply as does this report. Data from a municipal water supply have been analyzed in a comprehensive and standardized manner, categorized into functional costing categories and reaggregated, so that the cost of water as delivered to the consumer's tap can be defined.

Francis T. Mayo, Director
Municipal Environmental Research Laboratory

## ABSTRACT

Problems related to water supply have become increasingly important in recent years. Spreading urban boundaries force many potential water supply customers to locate farther and farther away from available water sources, thereby increasing the costs which must be incurred in order to provide adequate service. Therefore, it is important to systematically and objectively study the factors which affect the costs of water supply management.

This report utilizes the Cincinnati Water Works of Cincinnati, Ohio, for a case study to examine these factors and to document the application of a functional approach to the analysis of water supply costs. Such an approach can provide the basis for determining the cost of service for any given consumer within the Water Works service area. Ultimately the functional costing approach outlined in this report, or one similar in nature, will of necessity be used to analyze the impact of regional water supply systems.

Data for 10 years are analyzed for each of the functional categories of: Support Services; Acquisition; Purification; Power and Pumping; and, Transmission. Operating and Maintenance costs, Capital costs, and Labor costs are evaluated. A system evaluation is performed, in which the above costs are aggregated in such a way as to develop "cost zones" for the Water Works service area. Cost comparisons are made between actual charges and constructed costs for the Water Works' 10 largest water users.

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## ACKNOWLEDGEMENTS

The writers would like to acknowledge the assistance of Mr. Charles Bolton, Superintendent, and Mr. William F. Reeves, Chief Engineer, of the Cincinnati Water Works, and the other members of Mr. Bolton's staff for their review and suggestions regarding the preparation of this report.

# INTRODUCTION

Problems related to water supply have become increasingly important in recent years. In the past, supplying water to the consumer was considered to be a routine matter, and water itself seemed to be available in almost unlimited quantities. But this is no longer the case in most parts of the United States today. Perhaps water itself is not a scarce resource, but the problems of supplying water of acceptable quality to an increasingly urban population is no longer a simple matter.[2] Spreading urban boundaries force many potential water supply customers to locate farther and farther away from available water sources. Some areas which are inherently water limited have attracted significant population growth, thereby straining the available water resource. A scarcity of the land, labor, and capital resources needed to convey water to places of useful application have contributed to these problems.

Therefore, it is important to systematically and objectively study the factors which affect the costs of water supply management. This report examines these factors for the Cincinnati Water Works of Cincinnati, Ohio, and documents the application of a functional approach to the analysis of water supply costs, which provides the basis for determining the cost of service for any given consumer within the Water Works service area. Ultimately the functional costing approach outlined in this report, or one similar in nature, will of necessity be used to analyze the impact of regional water supply systems.

The Cincinnati Water Works, owned and operated by the City of Cincinnati, is a self-sustaining public utility. It is metropolitan in both nature and scope since water is served to areas outside the city limits.

In 1955 the City of Cincinnati and Hamilton County joined in a contract which stipulated that the Cincinnati Water Works would serve approximately 80 percent of Hamilton County for a period of 30 years (Figure 1). In 1961 the Water Works contracted to serve a portion of Butler County and in 1967 a portion of Warren County was added.

The Cincinnati Water Works currently serves over 186,000 accounts through more than 3,785 miles of water mains.[1] It has been expanding at the rate of 3,000 accounts and 35 miles of mains each year. In 1974, the Water Works supplied approximately 840,000 people at a daily rate of 132.9 mil gal (almost 158 gal/cap/day). The amount of water supplied might be greater except for the large amount of well water available in the area to consumers who wish to develop their own supplies. One private water purveyor supplies approximately 17 mil gal per day for industrial use.

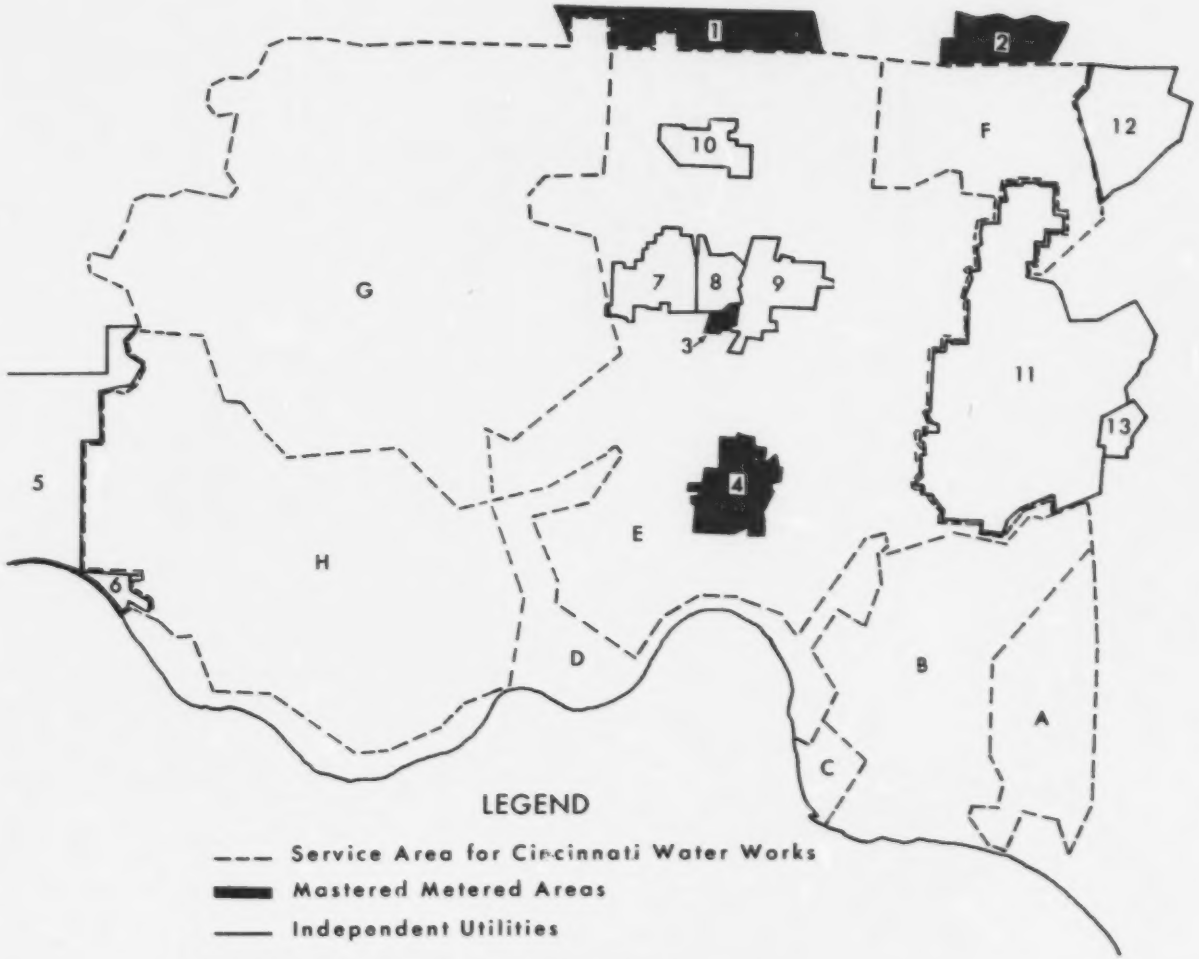



**FIGURE 1. Cincinnati Water Works service area**

To properly evaluate the factors which affect the costs of a complex urban activity, such as the Cincinnati Water Works, it is important to develop flexible and incisive data-gathering techniques. The approach taken in gathering the utility data is described in the following section.

## DATA GATHERING PROCEDURES

Water supply systems are generally composed of (1) collection works, (2) purification systems, where needed, and (3) transportation and distribution systems. The collection works either tap a source of water that can satisfy present and reasonable future demand on a continuous basis, or they convert an intermittent source into a continuous supply by storing surplus water for use during periods of low flows. If the water is not of satisfactory quality at the point of collection, it is treated to make it esthetically attractive and palatable.

Water containing iron or manganese is subjected to deferrization or demanganization; corrosive water is stabilized chemically; and excessively hard water is softened. The transportation and distribution works convey the collected and treated water to the community, where it is distributed to the consumers.

Because large operating and capital investments are involved, it is important to be able to compare costs between utilities to understand the components which make up the operation[3]. To make these kinds of comparisons it is necessary to collect the data in a standardized manner. One approach, and the one which will be utilized in this report, is to define the utility's operations in such a manner that they can be categorized into functional areas. Figure 2 illustrates a typical utility in which the operations have been defined as being composed of the functions of acquisition, treatment, and distribution. This is an oversimplified categorization but serves as a useful beginning point. One important area not included is the management function. By collecting data that describe these functional categories it is (in theory) possible to compare the costs of one water supply with those of another. This is the principle that has been used to gather data on the Cincinnati Water Works, although the functional categorizations are much more detailed than presented in the example.

The Cincinnati Water Works operations have been defined as follows: acquisition, purification, transmission and distribution, power and pumping, and support services. These functional categories are common to all water utility operations although the specific costs assigned to each functional category may vary depending on the utility. All of the costs, with the exception of the support services category, are those which make that specific activity operational. Support services includes management, customer services, and all of those costs which do not relate to specific operating activities, For example, laboratory personnel costs are included in the purification activity, but the management costs of the purification treatment division are included in the support services category. Maintenance and repair costs are allocated to each category where appropriate.

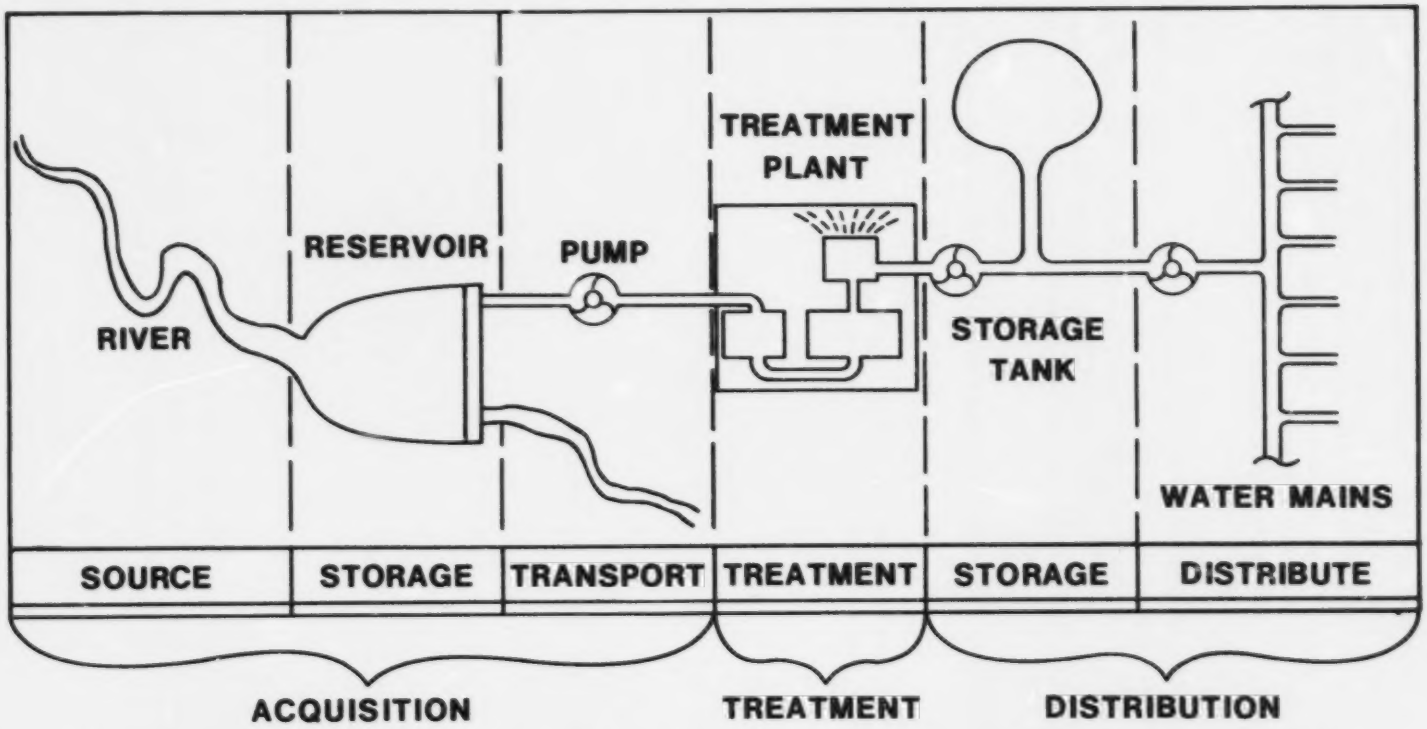



**FIGURE 2. SCHEMATIC DIAGRAM OF ACQUISITION, TREATMENT AND DISTRIBUTION FUNCTIONS FOR A TYPICAL WATER SUPPLY SYSTEM**

In addition to the Operating Costs, one must also include Capital Costs in the analysis in order to be complete. For the purposes of this analysis, Capital Costs are defined as the depreciation on the utility's existing plant in service, and the interest on any types of borrowing mechanisms which the utility may use to raise money for capital investment. Depreciation as reported here is based on the actual cost of the facility divided by its useful life, and not on reproduction cost. The data as reported for depreciation, therefore, will reflect lower costs for older utilities. This is true in the case of the Cincinnati Water Works, since most of its facilities were built from 1930 to 1940. In order to understand the magnitude of the bias which such an assumption introduces, an analysis of the replacement cost for the utilities facilities has been made. Using a standardized construction cost index, the original cost of each facility currently in use has been inflated to a 1974 cost base[4]. The analysis is contained in a section which will follow. The interest costs are those which the utility has historically paid for money.

Table 1 summarizes the cost categories utilized in this analysis.

TABLE 1

COST CATEGORIES USED IN ANALYSIS

| |
|---|
| Operating Costs |
| Overhead |
| Acquisition |
| Purification |
| Transmission and Distribution |
| Power and Pumping |
| Capital Costs |
| Depreciation |
| Interest |

All of the cost analysis which will be discussed in this paper is based on revenue-producing water. The unit costs presented will be calculated using the revenue-producing water pumped by each utility during the water year from 1964 through 1973.

## SERVICE AREA

The present service area lies almost entirely within Hamilton County with fringe extensions into three adjoining counties. Although for the most part they are surrounded by the Cincinnati Water Works service area, a number of communities maintain their own systems (Figure 1). Emergency service is provided to most of them, but, as long as their source of supply can be maintained, most of the communities will not change their present status. The distribution area and the facilities used are shown in Figure 3. One city has its own distribution system, but is served by the Cincinnati Water Works.

The current source of supply is the Ohio River, from which water is pumped to the treatment plant. It has a capacity of 235 million gallons per day (mgd); in 1973 it treated an average of 136 mgd. Water is distributed to the east through a series of pumping stations and tanks. To the north and west, water passes through two gravity tunnels and through two pump stations into a large reservoir and is then repumped into outlying service areas.

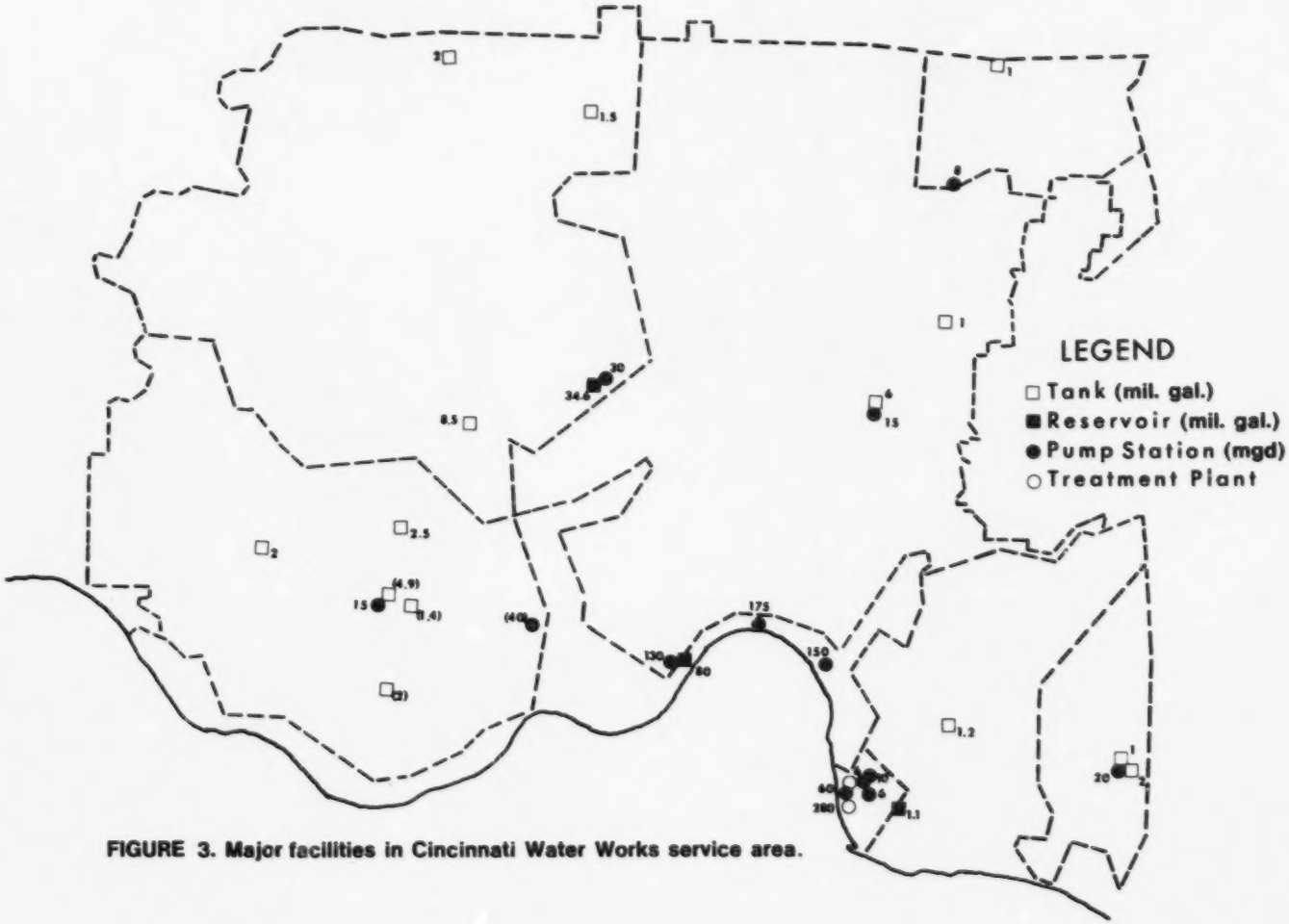



**FIGURE 3. Major facilities in Cincinnati Water Works service area.**

## COST ANALYSIS

Figure 4 shows the total water pumped by the utility during calendar years 1964 through 1973 as well as metered (revenue-producing) water and water which was accounted for but did not produce revenue. All cost data are based on revenue-producing water, for example, purification costs in dollars per million gallons ($/mil gal) are based on revenue-producing water and not on the total number of gallons of water pumped by the utility. As can be seen from Figure 4, the total water pumped exceeds revenue-producing water by nearly 13,000 mil gal in 1973.

Table 2 contains the total operating cost for each of the previously mentioned categories. The Support Services category includes all of those operating costs that support but are not directly chargeable to the production of water. It includes such items as general administration, accounting and collection, and meter reading. Subcategory "Other" includes pensions, workman's compensation, charges by other city departments, and security. The security costs increased sharply between 1968 and 1969 when fulltime guards were added to the Water Works staff. The Purification category includes those costs related to the cost of operating the laboratory, labor involved in the treatment function, chemicals for purifying the water, and maintenance of the treatment plant. Power and Pumping includes those costs related to operating labor, maintenance, and power for pumping water throughout the service area. The Transmission and Distribution category includes the operating labor and maintenance costs associated with supplying water to the consumer.

It can be seen from the table that the Support Services costs more than doubled between 1964 and 1973. Although all of the other cost categories increased during this period, their rate of increase was less than that of this category. Total operating costs increased by about 65 percent.

Table 3 contains the total average unit operating costs for each major category based on the number of revenue-producing gallons pumped in a given year. As can be seen, all the cost categories increased by a factor of less than two, and the total operating cost increased by about 40 percent.

Table 4 shows each cost category as a percent of total operating cost. It is obvious that Support Services accounted for a significant and increasing portion of the utility's budget, from approximately 26 percent in 1964 to 31.5 percent in 1973. The other cost categories either decreased or remained constant.

Table 5 contains the operating and capital expenses, as defined earlier, for the period. Depreciation and Interest Expense are defined as the capital

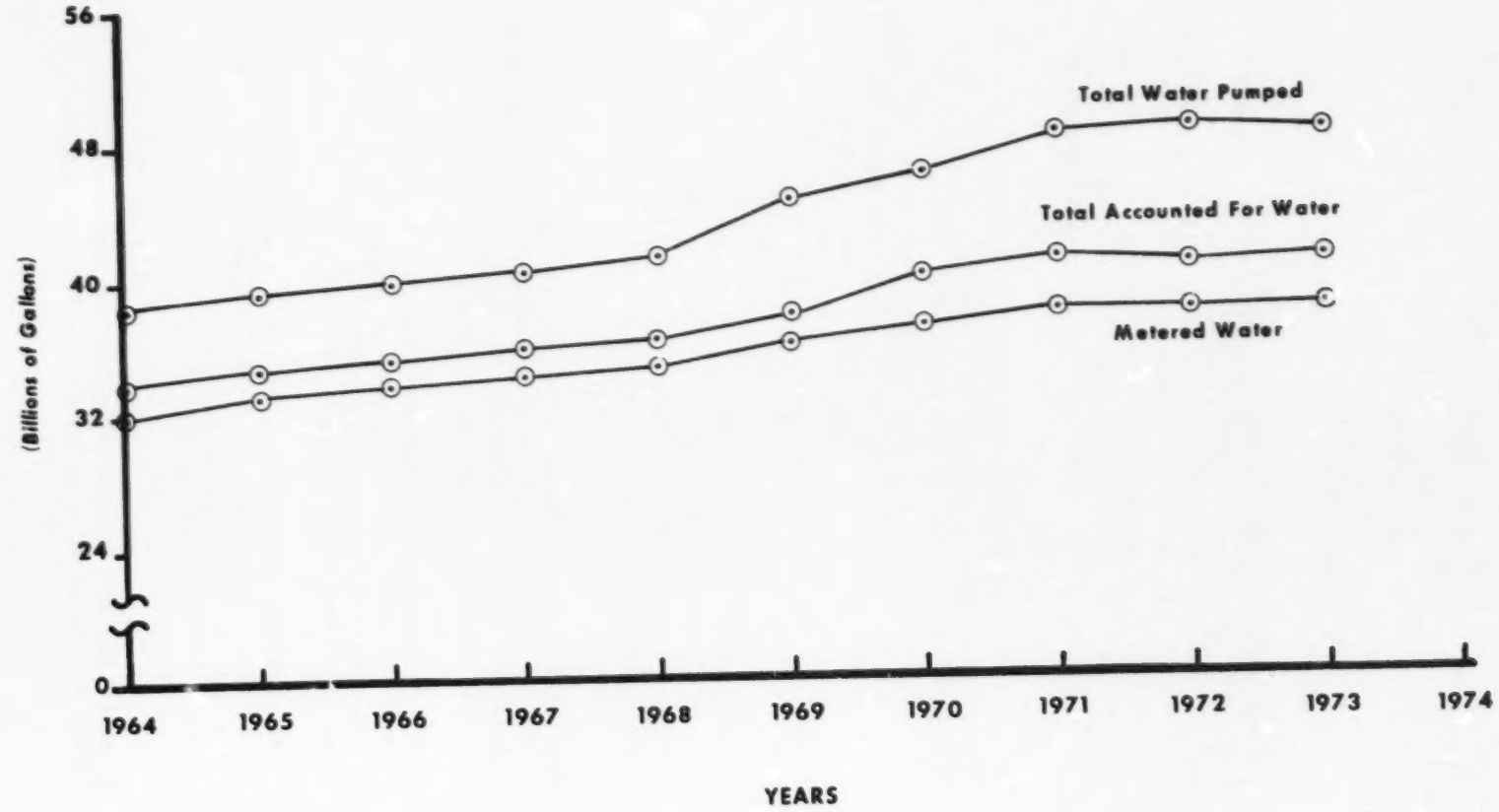



**FIGURE 4. Pumped and metered water for Cincinnati Water Works (1964-1973).**

TABLE 2

TOTAL OPERATING COSTS FOR MAJOR FUNCTIONAL CATEGORIES IN CINCINNATI WATER WORKS (DOLLARS)

| FUNCTIONAL CATEGORIES | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|---|---|---|---|
| SUPPORT SERVICES | | | | | | | | | | |
| ADMINISTRATION | 235,834 | 243,870 | 250,774 | 295,445 | 306,583 | 336,236 | 359,307 | 384,356 | 465,136 | 451,404 |
| ACCOUNTING AND COLLECTION | 282,963 | 278,983 | 292,656 | 324,660 | 395,372 | 410,427 | 422,221 | 480,680 | 533,285 | 585,288 |
| SERVICE | 225,768 | 233,539 | 245,552 | 249,206 | 256,748 | 302,611 | 300,214 | 351,596 | 370,723 | 407,787 |
| OTHER | 615,177 | 574,111 | 624,059 | 629,284 | 657,647 | 1,059,359 | 999,165 | 1,155,109 | 1,264,105 | 1,321,758 |
| TOTAL SUPPORT SERVICES | 1,359,742 | 1,330,503 | 1,413,041 | 1,498,595 | 1,616,350 | 2,108,633 | 2,080,907 | 2,371,741 | 2,633,249 | 2,766,237 |
| ACQUISITION | 394,844 | 368,762 | 374,229 | 372,385 | 379,928 | 405,149 | 426,743 | 496,344 | 480,020 | 485,102 |
| PURIFICATION | | | | | | | | | | |
| LABORATORY | 31,434 | 38,493 | 42,706 | 41,219 | 32,315 | 37,934 | 39,801 | 38,381 | 42,154 | 46,940 |
| OPERATING LABOR | 149,426 | 144,277 | 152,633 | 164,778 | 169,750 | 180,574 | 188,150 | 143,383 | 167,608 | 172,754 |
| CHEMICALS | 409,463 | 367,234 | 375,132 | 410,700 | 411,143 | 410,172 | 426,248 | 423,667 | 424,586 | 384,698 |
| MAINTENANCE OF PURIFICATION | 170,180 | 196,119 | 187,569 | 216,698 | 216,442 | 246,220 | 223,697 | 315,748 | 323,127 | 334,765 |
| OTHER | 152,710 | 160,352 | 175,827 | 171,299 | 182,267 | 166,132 | 187,145 | 243,424 | 282,744 | 270,910 |
| TOTAL PURIFICATION | 913,213 | 906,475 | 933,867 | 1,004,694 | 1,011,917 | 1,041,032 | 1,065,041 | 1,164,603 | 1,240,219 | 1,210,067 |
| POWER AND PUMPING | | | | | | | | | | |
| OPERATING LABOR | 199,620 | 202,322 | 223,715 | 232,845 | 228,061 | 255,809 | 272,235 | 239,756 | 232,280 | 238,806 |
| MAINTENANCE | 182,915 | 182,814 | 216,483 | 226,307 | 238,245 | 304,739 | 252,469 | 346,596 | 320,396 | 309,375 |
| POWER | 581,588 | 606,176 | 613,971 | 645,362 | 629,906 | 696,544 | 694,359 | 870,796 | 902,790 | 903,397 |
| OTHER | 122,039 | 124,036 | 128,545 | 151,493 | 150,925 | 154,805 | 163,001 | 181,262 | 179,479 | 215,554 |
| TOTAL POWER AND PUMPING | 1,086,162 | 1,115,348 | 1,182,714 | 1,256,007 | 1,247,137 | 1,411,897 | 1,382,064 | 1,638,410 | 1,634,945 | 1,667,132 |
| TRANSPORTATION & DISTRIBUTION | | | | | | | | | | |
| OPERATING LABOR | 462,986 | 450,387 | 475,763 | 491,722 | 534,062 | 570,439 | 595,005 | 611,769 | 607,511 | 652,791 |
| MAINTENANCE OF SYSTEM | 1,003,220 | 1,027,617 | 1,128,650 | 1,256,074 | 1,329,452 | 1,436,244 | 1,586,635 | 1,794,415 | 1,846,084 | 1,868,514 |
| OTHER | 91,989 | 75,792 | 106,959 | 137,468 | 64,201 | 77,331 | 141,096 | 80,963 | 152,840 | 132,579 |
| TOTAL TRANSMISSION & DIST. | 1,558,195 | 1,553,796 | 1,711,372 | 1,885,264 | 1,927,715 | 2,084,014 | 2,322,736 | 2,487,147 | 2,606,435 | 2,653,884 |
| TOTAL OPERATING EXPENSE | 5,310,156 | 5,274,886 | 5,615,223 | 6,016,945 | 6,183,047 | 7,050,725 | 7,277,491 | 8,158,245 | 8,594,868 | 8,782,422 |

TABLE 3

OPERATING COSTS FOR MAJOR FUNCTIONAL COST CATEGORIES IN CINCINNATI WATER WORKS
($/mil gal metered consumption)*

| FUNCTIONAL CATEGORIES | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|---|---|---|---|
| SUPPORT SERVICES | | | | | | | | | | |
| ADMINISTRATION | 7.36 | 7.38 | 7.44 | 8.65 | 8.83 | 9.29 | 9.68 | 10.08 | 12.26 | 11.84 |
| ACCOUNTING & COLLECTION | 8.82 | 8.44 | 8.68 | 9.50 | 11.39 | 11.34 | 11.38 | 12.61 | 14.06 | 15.37 |
| SERVICE | 7.04 | 7.06 | 7.28 | 7.30 | 7.39 | 8.36 | 8.09 | 9.22 | 9.78 | 10.70 |
| OTHER | 19.19 | 17.36 | 18.50 | 18.42 | 18.94 | 29.26 | 26.91 | 30.29 | 33.33 | 34.69 |
| TOTAL SUPPORT SERVICES | 42.41 | 40.24 | 41.90 | 43.87 | 46.55 | 58.25 | 56.06 | 62.20 | 69.43 | 72.60 |
| ACQUISITION | 12.25 | 11.15 | 11.10 | 10.90 | 10.94 | 11.19 | 11.50 | 13.02 | 12.66 | 12.73 |
| PURIFICATION | | | | | | | | | | |
| LABORATORY | .98 | 1.16 | 1.27 | 1.21 | .93 | 1.05 | 1.07 | 1.01 | 1.11 | 1.23 |
| OPERATING LABOR | 4.66 | 4.37 | 4.53 | 4.82 | 4.89 | 4.99 | 5.07 | 3.7 | 4.42 | 4.53 |
| CHEMICALS | 12.77 | 11.11 | 11.12 | 12.02 | 11.84 | 11.33 | 11.48 | 11.11 | 11.19 | 10.10 |
| MAINTENANCE OF PURIFICATION | 5.31 | 5.93 | 5.56 | 6.34 | 6.23 | 6.80 | 6.03 | 8.28 | 8.52 | 8.78 |
| OTHER | 4.76 | 4.85 | 5.21 | 5.02 | 5.25 | 4.59 | 5.04 | 6.38 | 7.46 | 7.11 |
| TOTAL PURIFICATION | 28.48 | 27.42 | 27.69 | 29.41 | 29.14 | 28.76 | 28.69 | 30.54 | 32.70 | 31.75 |
| POWER AND PUMPING | | | | | | | | | | |
| OPERATING LABOR | 6.23 | 6.12 | 6.63 | 6.82 | 6.57 | 7.07 | 7.33 | 6.29 | 6.12 | 6.27 |
| MAINTENANCE OF PUMPING | 5.70 | 5.53 | 6.42 | 6.63 | 6.86 | 8.42 | 6.80 | 9.90 | 8.45 | 8.12 |
| POWER | 18.14 | 18.34 | 18.21 | 18.89 | 18.14 | 19.24 | 18.71 | 22.84 | 23.80 | 23.71 |
| OTHER | 3.81 | 3.75 | 3.81 | 4.43 | 4.35 | 4.28 | 4.39 | 4.75 | 4.73 | 5.65 |
| TOTAL POWER AND PUMPING | 33.88 | 33.74 | 35.07 | 36.77 | 35.92 | 39.01 | 37.23 | 42.97 | 43.10 | 43.75 |
| TRANSMISSION AND DISTRIBUTION | | | | | | | | | | |
| OPERATING LABOR | 14.44 | 13.63 | 14.11 | 14.40 | 15.38 | 15.76 | 16.03 | 16.04 | 16.02 | 17.13 |
| MAINTENANCE OF SYSTEM | 31.29 | 31.08 | 33.46 | 36.77 | 38.29 | 39.68 | 42.75 | 47.07 | 48.67 | 49.04 |
| OTHER | 2.87 | 2.29 | 3.17 | 4.02 | 1.85 | 2.13 | 3.80 | 2.12 | 4.03 | 3.48 |
| TOTAL TRANSMISSION & DISTRIBUTION | 48.60 | 47.00 | 50.74 | 55.19 | 55.52 | 57.57 | 62.58 | 65.23 | 68.72 | 69.65 |
| AVERAGE TOTAL UNIT OPERATING COST | 165.62 | 159.55 | 166.50 | 176.14 | 178.07 | 194.78 | 196.06 | 213.96 | 226.61 | 230.48 |

* To convert to $/1000 cu m, multiply values in table by 0.26.

TABLE 4

OPERATING COST FOR FUNCTIONAL COST CATEGORIES IN CINCINNATI WATER WORKS
(COST AS A PERCENT OF TOTAL COST)

| FUNCTIONAL CATEGORIES | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|---|---|---|---|
| SUPPORT SERVICES | | | | | | | | | | |
| ADMINISTRATION | 4.4 | 4.6 | 4.5 | 4.9 | 4.9 | 4.8 | 5.0 | 4.7 | 5.4 | 5.1 |
| ACCOUNTING & COLLECTION | 5.3 | 5.3 | 5.2 | 5.4 | 6.4 | 5.8 | 5.8 | 5.9 | 6.2 | 6.7 |
| SERVICE | 4.3 | 4.4 | 4.4 | 4.1 | 4.2 | 4.3 | 4.1 | 4.3 | 4.3 | 4.7 |
| OTHER | 11.6 | 10.9 | 11.1 | 10.5 | 10.6 | 15.0 | 13.7 | 14.2 | 14.7 | 15.0 |
| TOTAL SUPPORT SERVICES | 25.6 | 25.2 | 25.2 | 24.9 | 26.1 | 29.9 | 28.6 | 29.1 | 30.7 | 31.5 |
| ACQUISITION | 7.4 | 7.0 | 6.7 | 6.2 | 6.1 | 5.8 | 5.9 | 6.1 | 5.6 | 5.5 |
| PURIFICATION | | | | | | | | | | |
| LABORATORY | .6 | .7 | .8 | .7 | .5 | .5 | .5 | .5 | .5 | .5 |
| OPERATING LABOR | 2.8 | 2.7 | 2.7 | 2.7 | 2.8 | 2.6 | 2.6 | 1.7 | 1.9 | 2.0 |
| CHEMICALS | 7.7 | 7.0 | 6.7 | 6.8 | 6.7 | 5.8 | 5.8 | 5.2 | 4.9 | 4.4 |
| MAINTENANCE & PURIFICATION | 3.2 | 3.7 | 3.3 | 3.6 | 3.5 | 3.5 | 3.1 | 3.9 | 3.8 | 3.8 |
| OTHER | 2.9 | 3.1 | 3.1 | 2.9 | 2.9 | 2.4 | 2.6 | 3.0 | 3.3 | 3.1 |
| TOTAL PURIFICATION | 17.2 | 17.2 | 16.6 | 16.7 | 16.4 | 14.8 | 14.6 | 14.3 | 14.4 | 13.8 |
| POWER AND PUMPING | | | | | | | | | | |
| OPERATING LABOR | 3.8 | 3.8 | 4.0 | 3.9 | 3.7 | 3.6 | 3.7 | 2.9 | 2.7 | 2.7 |
| MAINTENANCE OF PUMPING | 3.4 | 3.5 | 3.8 | 3.8 | 3.9 | 4.3 | 3.5 | 4.2 | 3.7 | 3.5 |
| POWER | 11.0 | 11.5 | 10.9 | 10.7 | 10.2 | 9.9 | 9.6 | 10.7 | 10.5 | 10.3 |
| OTHER | 2.3 | 2.3 | 2.3 | 2.5 | 2.4 | 2.2 | 2.2 | 2.2 | 2.1 | 2.5 |
| TOTAL POWER AND PUMPING | 20.5 | 21.1 | 21.0 | 20.9 | 20.2 | 20.0 | 19.0 | 20.0 | 19.0 | 19.0 |
| TRANSMISSION AND DISTRIBUTION | | | | | | | | | | |
| OPERATING LABOR | 8.7 | 8.6 | 8.5 | 8.1 | 8.6 | 8.1 | 8.2 | 7.5 | 7.0 | 7.4 |
| MAINTENANCE OF SYSTEM | 18.9 | 19.5 | 20.1 | 20.9 | 21.5 | 20.3 | 21.8 | 22.0 | 21.5 | 21.3 |
| OTHER | 1.7 | 1.4 | 1.9 | 2.3 | 1.1 | 1.1 | 1.9 | 1.0 | 1.8 | 1.5 |
| TOTAL TRANSMISSION & DISTRIBUTION | 29.3 | 29.5 | 30.5 | 31.3 | 31.2 | 29.5 | 31.9 | 30.5 | 30.3 | 30.2 |
| TOTAL OPERATING EXPENSE | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

TABLE 5

CAPITAL AND OPERATING COSTS FOR CINCINNATI WATER WORKS (DOLLARS)

| COST ITEM | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|---|---|---|---|
| OPERATING EXPENSE | 5,310,156 | 5,274,886 | 5,615,223 | 6,016,945 | 6,183,047 | 7,050,725 | 7,277,491 | 8,158,245 | 8,594,868 | 8,782,422 |
| DEPRECIATION | 1,177,441 | 1,230,236 | 1,421,671 | 1,549,928 | 1,605,070 | 1,633,727 | 1,632,017 | 1,656,520 | 1,699,258 | 1,771,299 |
| INTEREST EXPENSE | 826,052 | 947,251 | 926,933 | 877,190 | 887,150 | 887,103 | 792,755 | 802,055 | 710,555 | 669,455 |
| TOTAL | 7,313,650 | 7,452,373 | 7,963,827 | 8,444,063 | 8,665,267 | 9,571,465 | 9,702,263 | 10,616,820 | 11,004,681 | 11,223,176 |
| TOTAL COST PER MILLION GALLONS* | 228.10 | 225.41 | 236.14 | 247.19 | 249.56 | 264.41 | 261.39 | 278.45 | 290.14 | 294.54 |

* Multiply value in table 0.26 to convert to $\$/10^3 M^3$.

expenses for the waterworks system. These capital expenses remained essentially constant but operating expenses increased by approximately 65 percent. As can be seen from Table 6, the percent of expenditures allocated to capital decreased from approximately 27 percent to 22 percent during the period. Operating expenditures are always reported in inflated or current dollars, while capital expenditures are depreciated in historical dollars over a long period of time. The problems related to the depreciation of capital will be discussed later. Since the Support Services category, which is labor intensive, played an increasingly important role in the cost of water supply, labor and manpower costs will be analyzed in the following section.

## Labor Cost Analysis

To evaluate the impact of labor costs on operating costs for water supply, it is necessary to examine the payroll of the water utility (Table 7). It can be seen that labor costs accounted for 64 percent of the utility's operating costs in 1964 and for 62 percent in 1973. The average cost per man-hour increased 71 percent, while the number of man-hours/mil gal of metered consumption decreased by 23 percent. The bottom line in the table shows a decreasing capital/labor cost ratio. Although economies of scale were achieved with respect to the number of man-hours used to produce water, the effect on cost was nullified by wage increases. The table, therefore, illustrates the importance of labor in what is typically presumed to be a capital intensive industry.

## Depreciation Analysis

As mentioned earlier, capital expenditures comprise a large portion of the cost of water supply. Depreciation reflects historical costs and not the cost of replacing a capital facility based on current costs. Historical costs refer to the original construction cost of a capital facility, while reproduction costs reflect the capital expenditures necessary to build an identical plant today. Historical cost is exact, but reproduction cost is based on the original investment modified by an appropriate index.

The records of the Cincinnati Water Works show the historical value of the plant-in-service to be $111,700,315. The value of pipelines, plant, or equipment previously replaced or fully depreciated is excluded.

Using the historical costs, a reproduction cost was calculated using the ENR Building Cost Index (1913 = 100) for buildings and equipment and the ENR Construction Cost Index (1903 = 100) for pipes and valves. (A skilled labor cost factor is used to compute the Building Cost Index, and a common labor cost factor is used to compute the Construction Cost Index.) Having weighted these capital expenditures with the proper indices, a reproduction cost of $458,990,287 was found for the current plant-in-service, which represents a 311 percent increase over the historical value. These capital expenditures do include capital investment in a new treatment plant (Great Miami) which is expected to be operational soon. Derivation of a reproduction value facilitates examining the impact of inflation on capital cost and the current

worth of capitals contribution to output. The computations discussed in this section are summarized in Table 8.

TABLE 6

OPERATING AND CAPITAL EXPENDITURE RATIOS
FOR CINCINNATI WATER WORKS

| COST ITEM | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|---|---|---|---|
| OPERATING EXPENSE | 5,310,156 | 5,274,886 | 5,615,223 | 6,016,945 | 6,183,047 | 7,050,725 | 7,277,491 | 8,158,245 | 8,594,868 | 8,782,422 |
| CAPITAL EXPENSE | 2,033,494 | 2,177,487 | 2,348,604 | 2,427,118 | 2,492,220 | 2,520,740 | 2,424,772 | 2,458,575 | 2,409,813 | 2,440,754 |
| (Interest) | (826,052) | (947,251) | (926,933) | (877,190) | (887,150) | (887,013) | (792,755) | (802,055) | (710,555) | (669,955) |
| TOTAL | 7,313,650 | 4,452,373 | 7,963,827 | 8,444,063 | 8,675,267 | 9,571,465 | 9,702,263 | 10,616,820 | 11,004,681 | 11,223,176 |
| OPERATING EXPENSE (% of TOTAL) | 72.61 | 70.78 | 70.51 | 71.25 | 71.35 | 73.66 | 75.01 | 75.84 | 78.10 | 78.25 |
| CAPITAL EXPENSE (% of TOTAL) | 27.39 | 29.22 | 29.49 | 28.75 | 28.65 | 26.34 | 24.99 | 24.16 | 21.90 | 21.75 |

TABLE 7

MANPOWER COSTS FOR CINCINNATI WATER WORKS

| COST ITEM | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 |
|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL PAYROLL | 3,393,575 | 3,399,082 | 3,664,567 | 3,946,864 | 4,085,948 | 4,446,863 | 4,467,360 | 4,979,657 | 5,261,055 | 5,474,585 |
| TOTAL HOURS ON PAYROLL | 1,110,032 | 1,116,220 | 1,102,892 | 1,120,980 | 1,148,588 | 1,141,448 | 1,115,744 | 1,094,229 | 1,071,476 | 1,046,724 |
| METERED CONSUMPTION (mil gal)* | 32,063 | 33,061 | 33,725 | 34,160 | 34,722 | 36,199 | 37,117 | 38,128 | 37,928 | 38,104 |
| TOTAL PAYROLL METERED ($/mil gal) | 105.840 | 102.812 | 108.660 | 115.540 | 117.676 | 122.845 | 120.358 | 130.604 | 138.711 | 143.675 |
| TOTAL HOURS METERED CONSUMPTION ($/mil gal)* | 34.62 | 33.76 | 32.70 | 32.81 | 33.08 | 31.53 | 30.06 | 28.70 | 28.25 | 27.47 |
| AVERAGE COST PER MAN HOUR | 3.06 | 3.04 | 3.32 | 3.52 | 3.56 | 3.89 | 4.00 | 4.55 | 4.91 | 5.23 |
| CAPITAL/LABOR COST RATIO | 0.60 | 0.64 | 0.64 | 0.61 | 0.61 | 0.57 | 0.54 | 0.49 | 0.46 | 0.45 |

* To convert to 1000 cu m and $/1000 cu m, multiply by 0.26.

TABLE 8

HISTORICAL AND REPRODUCTION COSTS OF PLANT-IN-SERVICE
FOR CINCINNATI WATER WORKS (DOLLARS)

| Capital Facility | Historical Cost | Reproduction Cost (1973-74 Dollars) |
|---|---|---|
| Plant | 42,649,160 | 146,981,272 |
| Pipe | 54,848,943 | 296,771,626 |
| Misc. Plant* | 13,202,213 | 15,237,389 |
| Total | 110,700,315 | 458,990,286 |

* Capital expenditures which are not specifically identified.

## SYSTEM EVALUATION

Using the cost data for the various functional areas discussed earlier, costs were allocated to specific treatment, transmission, storage, and pumping facilities in the system. A general cost was determined for distribution, interest, and overhead. Using costs based on 1973 $/mil gal and assuming a linear allocation of costs for a given area against capacity required to serve it, the facility costs associated with each service area, such as pumping and storage, were established as shown in parentheses in Figure 5.

The codes in the schematic diagram (Figure 5) can be related to the cost values in Tables 9 and 10. For example, the acquisition cost for water from the Ohio River, including depreciation of the facility and operating costs, is $16.70/mil gal. As a unit of water (mil gal) moves through each facility to another service area, the unit cost of moving water through that area is added to the cost of getting water to that area, thereby creating the incremental costs shown in Table 10. The facility and transmission costs are added to the costs of distribution, interest, and overhead to yield an average unit cost to serve that area. A service zone represents a customer service area and a demand point for water. For purposes of this analysis an attempt was made to discriminate between the water demanded in a given distribution area and the water transmitted through the area into the next service zone.

To illustrate the way in which cost changes from one service area to another, we can examine the B1 and B2 cost areas (Figure 6). The costs for each zone are taken from Table 10, as shown in the schematic diagram. The cost per million gallons for area B1 is composed of acquisition cost ($16.70), treatment cost ($36.05), pumping and storage cost ($55.37), transmission cost ($75.43), distribution cost ($50.52), interest cost ($17.57), and overhead cost ($85.22). This yields a total cost of $336.86/mil gal. For the B2 area, the pumping and storage costs ($80.45) and the transmission costs ($60.26) must be added to the B1, and this yields a cost of $477.60/mil gal. These values are plotted in Figure 7. The costs in each zone are described by a step function. As water is pumped from the treatment plant through the B1 zone, the average cost per million gallons (using this analysis) remains constant, however, as water is repumped into the B2 zone, the costs take a definable jump to a higher level.

The step function suggests the possibility that as additional service zones are added to the periphery of the utility service area the cost functions will continually increase. It is revealing to compare this costing analysis to the prices actually charged in the utility service area.

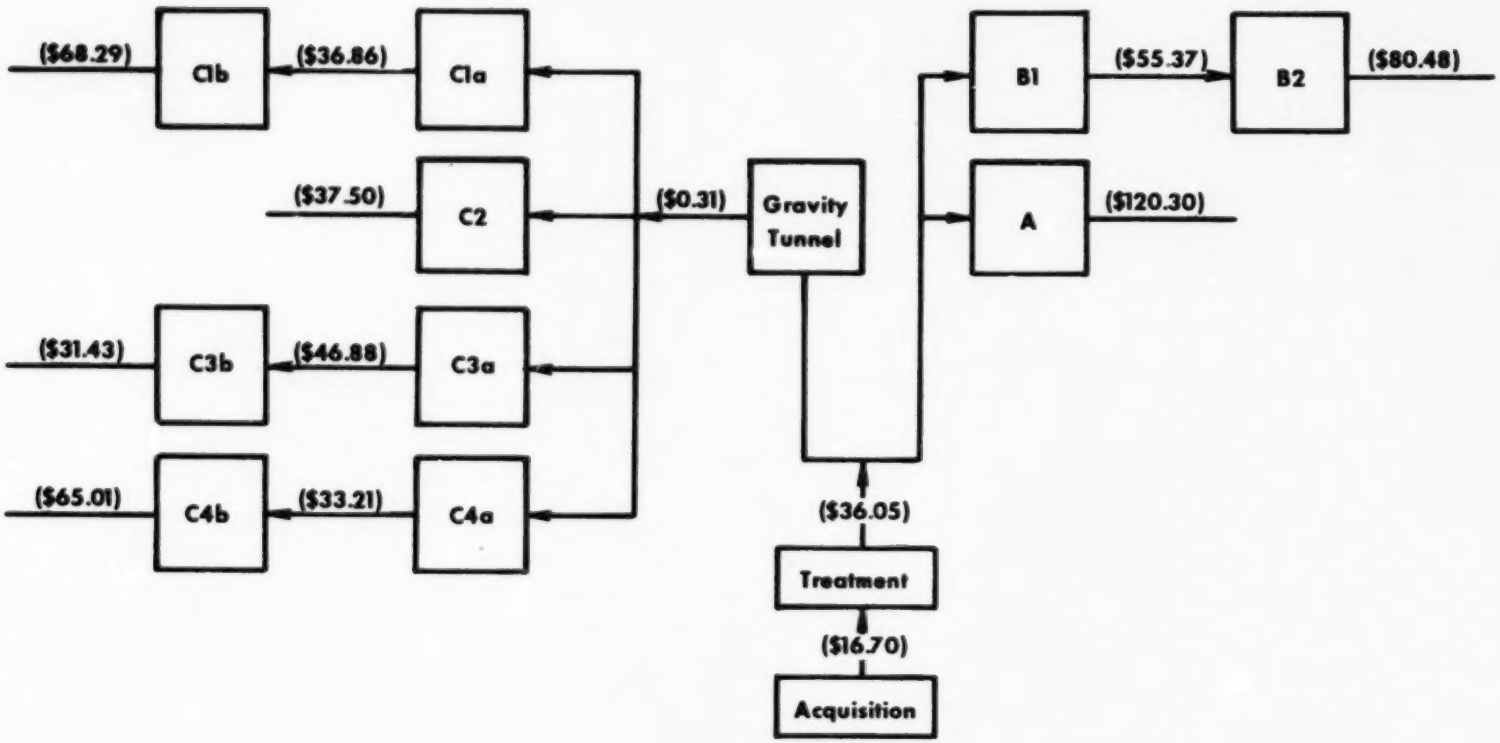



**FIGURE 5. Schematic diagram of facility costs in Cincinnati Water Works system.**

**(To convert $/mil gal to $/1000 cu m, multiply by 0.26.)**

TABLE 9

TRANSMISSION COSTS BETWEEN SERVICE AREAS
($/mil gal)* +

| From | To A | Bl | B2 | Cla | Clb | C2 | C3a | C3b | C4a | C4b |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatment Plant | 78.14 | 75.43 | - | 19.76 | - | 28.93 | 22.29 | - | 24.98 | - |
| Bl | - | - | 60.26 | - | - | - | - | - | - | - |
| Cla | - | - | - | - | 113.61 | - | - | - | - | - |
| C3a | - | - | - | - | - | - | - | 39.45 | - | - |
| C4a | - | - | - | - | - | - | - | - | - | 50.03 |

* To convert to $/1000 cu. m., multiply by 0.26.

+ See Figures 5 and 8 for relationship between service area names and their geographic locations.

TABLE 10

COST, CONSUMPTION, AND REVENUE DATA BY CINCINNATI WATER WORKS SERVICE AREA (1973)

| Area | Incremental ($/mil gal)* | Total ($/mil gal)*+ | Metered Consumption (gal) | Revenue ($) |
|---|---|---|---|---|
| A | 251.19 | 404.50 | 190,150 | 76,915.68 |
| B1 | 183.55 | 336.86 | 629,050 | 211,901.78 |
| B2 | 324.29 | 477.60 | 339,991 | 162,379.70 |
| C1a | 109.68 | 262.99 | 6,796,811 | 1,787,493.30 |
| C1b | 291.58 | 444.89 | 290,806 | 129,376.68 |
| C2 | 119.49 | 272.80 | 9,667,159 | 2,637,200.90 |
| C3a | 122.23 | 275.54 | 3,784,174 | 1,042,691.30 |
| C3b | 193.11 | 346.42 | 3,873,248 | 1,341,770.50 |
| C4a | 111.25 | 264.56 | 7,640,334 | 2,021,326.70 |
| C4b | 226.29 | 379.60 | 4,859,095 | 1,844,512.40 |
| Total | | | 38,070,818 | 11,255,568.94 |

* To convert to $/1000 cu m, multiply by 0.26.

\+ Includes distribution (50.52), interest (17.57), and overhead (85.22).

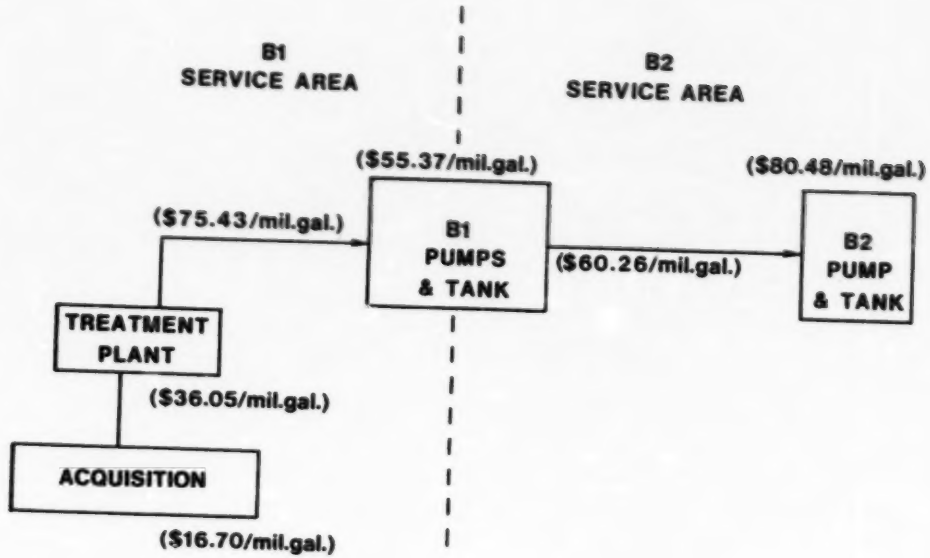



**FIGURE 6. Schematic diagram of incremental costs for B1 and B2 service areas. (To convert $/mil gal to $/1000 cu m, multiply by 0.26.)**

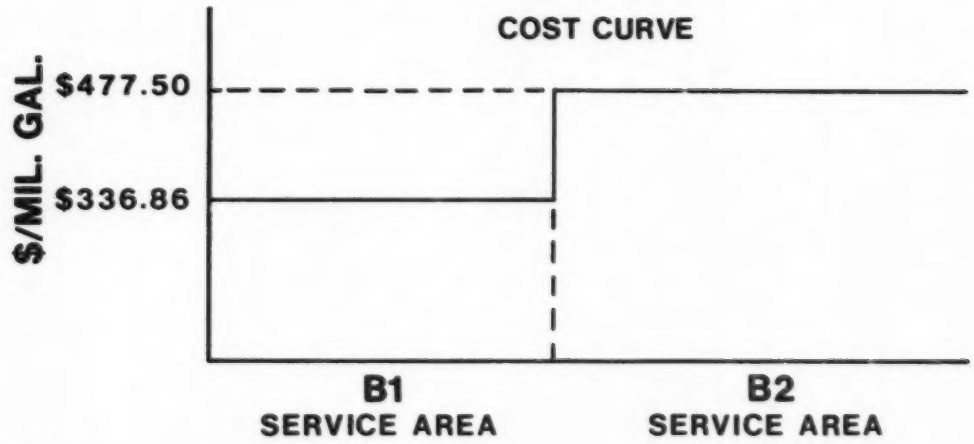



**FIGURE 7. Step function cost curve for B1 and B2 service areas.**

**(To convert $/mil gal to $/1000 cu m, multiply by 0.26.)**

## Pricing Analysis

Table 11 contains the price in dollars per million gallons for the top 10 users for 1973 in the Cincinnati Water Works service area. It can be seen from Table 11 and Figure 8 that in the city the Davison Chemical Company paid from a low of $87.54/mil gal to a high of $180.26/mil gal per month. These data are based on utilization of water for 1973, and on the rates shown in Table 12.

However, the lowest cost for water delivered to a service area is for the water to area C1a ($262.99/mil gal). Figure 8 is a map which compares the cost areas defined in this report and also depicts the 10 major users for the area. It allows for an easy visual comparison between the data in Figure 5 and Table 11. These data are summarized in Table 13, which compares the cost and revenues from various levels of water used for the 10 major users in the water works billing area. It can be seen that many of the major users are not meeting the costs of supplying water to them.

Table 13 (column 3) presents a cost comparison based on the assumption that each of the costs in the Acquisition, Treatment, Transmission and Distribution, Power and Pumping, Support Services, and Capital cateogry can be based on a cost per million gallons basis. Such an assumption might be questioned, particularly as it relates to Support Services.

An alternate means of cost allocation to the 10 largest users may be generated through adjustment of Support Services cost per million gallons to overhead cost per customer.

Total Support Services is $2,766,237 which, when divided by total metered water, gives a Support Services cost of $72.60/mil gal. The remaining $12.62/mil gal included in the $85.22 Support Services cost refers to miscellaneous capital and operating expenditures not counted in the incremental costs for each service area.

The $72.60/mil gal cost can be reallocated on a per customer basis, since there are 186,910 quarterly accounts and 1,533 monthly accounts. Monthly billed customers require three times as many meter readings, yielding a total number of equivalent quarterly accounts of 191,509. Therefore, Support Services cost per quarterly customer is $14.44.

For the 10 largest users, which are monthly accounts, the Support Services cost is $43.32 per customer (three times that for the quarterly customers). Adding this adjusted overhead cost to the incremental, interest, acquisition, treatment, distribution, transmission, and miscellaneous Support Services cost for each zone results, the total costs to supply the 10 largest customers are shown in column 4 of Table 13.

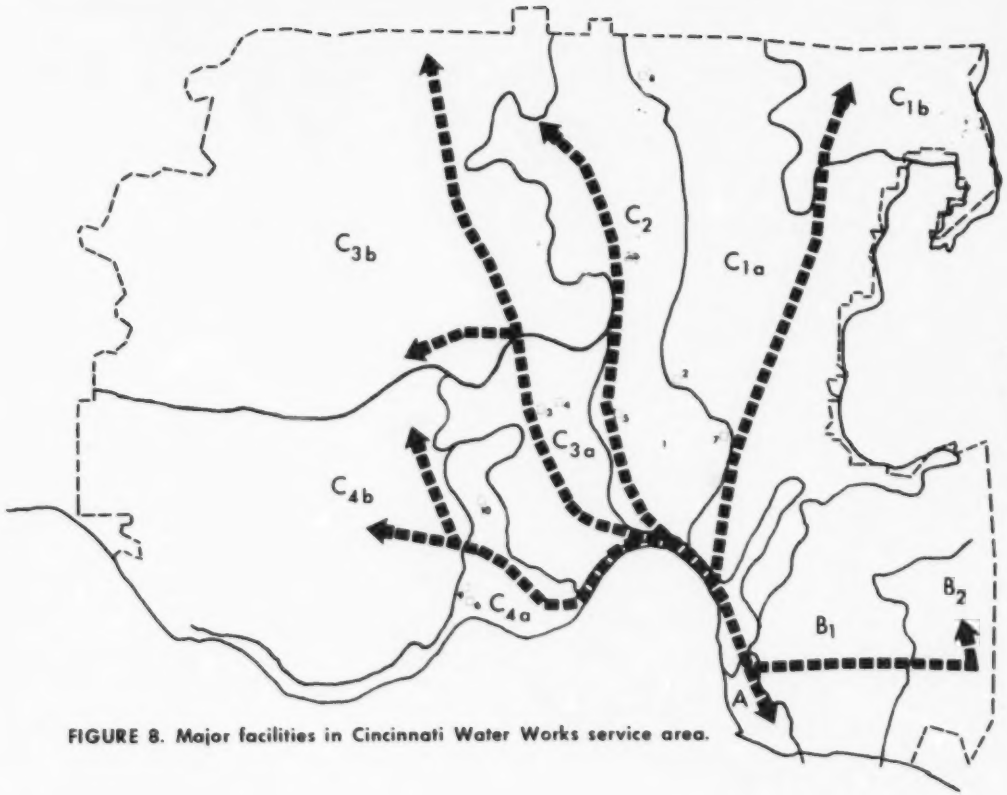
It can be seen by comparing columns 3 and 4 of Table 13 that the adjusted cost approach lowers the costs for the 10 major users but it will raise the proportion of Support Services which the other users must bear.

TABLE 11

TEN MAJOR USERS OF WATER FROM CINCINNATI WATER WORKS

| MAJOR USERS | | MONTH | UNITS USED (mil gal) | BILLED ($) | ($/mil gal)* | REMARKS |
|---|---|---|---|---|---|---|
| CITY OF NORWOOD | HIGH | 11 | 1.64 | $ 48,112.24 | $294.12 | SUBURB |
| | LOW | 3 | 1.12 | 33,046.20 | 294.12 | |
| HILTON DAVIS | HIGH | 2 | 0.56 | 9,464.44 | 168.83 | CITY |
| | LOW | 1 | 0.33 | 5,773.96 | 174.67 | |
| SUN CHEMICAL | HIGH | 9 | 0.51 | 8,642.84 | 169.87 | CITY |
| | LOW | 11 | 0.32 | 5,612.72 | 175.44 | |
| PROCTOR & GAMBLE | HIGH | 7 | 0.46 | 14,232.55 | 308.70 | SUBURB |
| | LOW | 2 | 0.31 | 9,829.27 | 321.12 | |
| DAVISON CHEMICAL | HIGH | 7 | 0.62 | 5,457.40 | 87.54 | CITY |
| | LOW | 12 | 0.23 | 4,154.56 | 180.26 | |
| METROPOLITAN SEWER | HIGH | 12 | 0.33 | 5,822.88 | 175.19 | CITY |
| | LOW | 6 | 0.20 | 3,638.88 | 185.44 | |
| CINCINNATI MILACRON | HIGH | 7 | 0.35 | 6,097.44 | 175.07 | CITY |
| | LOW | 4 | 0.23 | 4,166.40 | 187.95 | |
| KROGER COMPANY | HIGH | 7 | 0.24 | 7,538.95 | 313.54 | SUBURB |
| | LOW | 8 | 0.17 | 5,447.98 | 328.26 | |
| KROGER COMPANY | HIGH | 7 | 0.23 | 4,167.12 | 181.90 | CITY |
| | LOW | 12 | 0.13 | 2,607.72 | 197.73 | |
| E. KAHN'S SONS | HIGH | 5 | 0.23 | 4,230.68 | 181.67 | CITY |
| | LOW | 11 | 0.14 | 2,778.44 | 195.17 | |

* To convert to $/1000 cu m, multiply by 0.26.




**TEN LARGEST USERS**

1. City of Norwood
2. Hilton Davis
3. Sun Chemical
4. Proctor and Gamble
5. Davison Chemical
6. Metropolitan Sewer District
7. Cincinnati Milacron
8. Kroger Company
9. Kroger Company
10. E. Kahn's and Son's

**FIGURE 8. Major facilities in Cincinnati Water Works service area.**

TABLE 12

CINCINNATI WATER WORKS WATER RATES
Effective April 1, 1969

| CRITERIA | | MINIMUM CHARGES | | | | | |
|---|---|---|---|---|---|---|---|
| | | Inside Cincinnati | | Outside Cincinnati in Hamilton and Clermont Counties | | Butler and Warren Counties | |
| Meter Size (in) | Family Units (number) | Monthly | Quarterly | Monthly | Quarterly | Monthly | Quarterly |
| 5/8 | 1 | $ 2.50 | $ 4.50 | $ 5.00 | $ 9.00 | $ 5.75 | $ 10.35 |
| 3/4 | 2 - 3 | 2.80 | 5.40 | 5.60 | 10.80 | 6.45 | 12.40 |
| 1 | 4 - 5 | 3.50 | 7.50 | 7.00 | 15.00 | 8.05 | 17.25 |
| 1-1/2 | 6 - 12 | 4.50 | 10.50 | 9.00 | 21.00 | 10.35 | 24.15 |
| 2 | 13 - 20 | 7.00 | 18.00 | 14.00 | 36.00 | 16.10 | 41.40 |
| 3 | 21 - 50 | 9.00 | 24.00 | 18.00 | 48.00 | 20.70 | 55.20 |
| 4 | 55 - 115 | 12.00 | 33.00 | 24.00 | 66.00 | 27.00 | 75.00 |
| 6 | 116 - 250 | 25.00 | 75.00 | 50.00 | 150.00 | 57.00 | 170.00 |
| 8 | over 250 | 35.00 | 105.00 | 70.00 | 210.00 | 80.00 | 240.00 |
| 10 | | 40.00 | 120.00 | 80.00 | 240.00 | 92.00 | 270.00 |
| 12 | | 40.00 | 120.00 | 80.00 | 240.00 | 92.00 | 270.00 |

| Per month | Per Quarter | COMMODITY CHARGES (C/100 cu ft) | | |
|---|---|---|---|---|
| 1,000 - 60,000 cu ft | 2,000 - 180,000 cu ft | 20 | 35 | 40 |
| 50,000 - 1 mil cu ft | 180,000 - 3 mil cu ft | 16 | 28 | 32 |
| Over 1 mil cu ft | Over 3 mil cu ft | 12 | 21 | 24 |

TABLE 13

ACTUAL CHARGE VERSUS COST COMPARISONS FOR TEN MAJOR USERS
IN CINCINNATI WATER WORKS
($/mil gal)*

| User | Revenue+ | Cost++ | Adjusted++ Cost |
|---|---|---|---|
| Norwood | 294.12 | 272.80 | 243.52 |
| Hilton Davis | 168.83<br>175.67 | 262.99 | 233.71 |
| Sun Chemical | 169.87<br>175.44 | 275.54 | 246.26 |
| Procter & Gamble | 308.70<br>321.12 | 275.54 | 246.26 |
| Davison Chemical | 87.54<br>180.26 | 272.80 | 243.57 |
| Metropolitan Sewer | 175.19<br>185.44 | 264.56 | 235.28 |
| Cincinnati Milacron | 175.07<br>187.95 | 272.80 | 243.52 |
| Kroger Company (Suburb) | 313.54<br>328.26 | 262.99 | 233.71 |
| Kroger Company | 181.90<br>197.73 | 264.56 | 235.28 |
| E. Kahn's Sons | 181.67<br>195.17 | 264.56 | 235.28 |

* To convert to $/1000 cu m, multiply by 0.26.

+ Wherever two values are presented, one represents the high and the other the low bill in $/mil gal for 1973-74.

++ These values were calculated on an average cost basis and as such do not reflect potential economies of scale which result from having large users in the system.

Note: Suburban users are charged at a higher rate to allow for expansion into Hamilton County.

Nevertheless, the same users that pay less than cost, as shown in column 3 of Table 13, also pay less than cost, as shown in column 4. Both approaches to cost allocation reveal an interesting picture of costs and the way they vary throughout the Cincinnati Water Works service area.

## SUMMARY AND CONCLUSIONS

This report documents the application of a functional approach to the analysis of water supply utility management costs. Functionally, these costs have been defined in the following manner: Support Services; Acquisition; Purification; Transmission; and, Power and Pumping. Having defined these costs in a functional manner, they can be reaggregated into capital and operating costs for the various physical components which make up the water delivery system. It is apparent from the first analysis that manpower costs are a significant part of water supply operating costs and that this factor is playing an increasingly important role in the total cost of water as delivered to the consumer. As water is pumped from treatment plant to consumer, costs are added, and they increase with respect to distance from the central supply. By using a specific utility as an example, this kind of analysis can be related to "real world" costs. However, it is obvious that the basic principles discussed apply to all water supplies and that they must be considered in planning and design of water systems. The functional analysis is extremely important for regional considerations. Perhaps the major choice facing most small to medium water supplies will be to join a larger water system or to develop and improve their own water supply systems.[4] The approach taken in this analysis should materially assist planners and policy makers in making these types of decisions.

## REFERENCES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5. S.433, Public Law 93-523, Safe Drinking Water Act, 93rd Congress, Washington, D. C. (Dec. 16, 1974).